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RESEARCH SUMMARY

forest sciences
NELSON FOREST REGION

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Field Identification and Quantification of *Armillaria ostoyae*

INTRODUCTION

In order to detect *Armillaria ostoyae* and to determine the extent of infection, field crews must be familiar with common symptoms and signs of the disease. Once identified and quantified accurately, appropriate forest management activities can be prescribed.

It is very difficult for a field person to distinguish between *A. ostoyae*, and *A. sinapina* (the other commonly occurring *Armillaria* species in B.C.). However, if conifers are being attacked and killed, then one can assume that the species responsible is *A. ostoyae*. *A. sinapina* is usually found as a saphrophyte living off dead hosts, or in dead tissues of hosts dying from other causes.

■ For further reading and good photographic references see Morrison et al. 1991

DISEASE SYMPTOMS

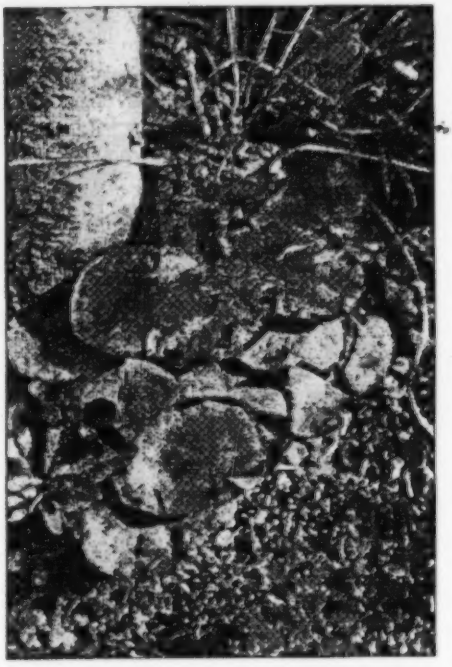
Symptoms of *Armillaria ostoyae* root disease vary considerably from tree to tree depending to a large extent on the location of the initial infection (infections closer to the root collar are more likely to cause mortality). The rate at which symptoms appear depends to some extent on tree age. Younger trees are generally more susceptible than older trees, and disease symptoms and mortality tend to occur more rapidly in young trees.

Often, the first symptoms to appear on infected trees are crown symptoms, followed by stress crops of cones, basal stem indicators, and finally mortality. In addition to symptoms seen on individual trees, *Armillaria* infection may also be evident from stand level indicators that signal root rot centers.

Stand Level Indicators

At the stand level, symptoms of *Armillaria* infection include pockets of deciduous trees, scattered openings containing or surrounded by dead and dying trees, and at times, poor stand vigour.

Armillaria ostoyae infected trees that fall over due to decayed or weakened roots will land in a characteristic crisscrossed pattern on the ground. In contrast, trees blown over by strong winds usually lie parallel to one another in the direction of prevailing winds (2). The exposed roots of infected fallen trees are shorter than healthy roots and may have a snubbed off appearance. Mycelial fans and/or decay should be readily evident in uprooted and broken trees.



***Armillaria ostoyae* mushrooms on Douglas fir**

Crown Indicators

A common symptom of *Armillaria* infection is a decline in growth of the host plant (1). This occurs because *Armillaria* physically disrupts the host plant's vascular system. Infected structural roots are damaged or killed and this reduction in root volume reduces the plants ability to obtain moisture and nutrients.

Reduced shoot growth and a more rounded crown are symptoms of older trees that have been infected with *Armillaria* for many years (3). Foliage gradually becomes stunted and chlorotic, and becomes quite sparse as the tree sheds older needles. Often, only two to three years of foliage will remain at the ends of the branches. These symptoms generally appear when more than half of the roots are dead (4).

This decline may not be apparent in trees younger than ten years old because infected trees are often killed before growth reduction becomes apparent. These trees will often take on a chlorotic appearance shortly before death. Following death, red or brown foliage may persist on these trees for up to a year. Some species may retain their needles for several years following tree death (i.e. 2 to 5 years for subalpine fir).

Stress-Induced Reproduction
Stress caused by *Armillaria* infection may induce a tree to produce a crop of cones that are smaller than normal, but more numerous. This increased cone crop usually occurs in the growing season before death (3).

Basal Stem Indicators
Resinosis, or pitching at the base or lower bole of a tree, is another common symptom of *A ostoyae* infection. Infected conifers attempt to repel the fungus by exuding resin, which leaks through cracks in the outer bark of the tree and appears as basal resinosis. However, resinosis usually does not occur until *Armillaria* has reached the root collar of the host tree, and by this time, the fungus is often well established in the root system of the tree. Resinosis is not always obvious on infected trees, especially in thick-barked species such as Douglas fir. Resinosis on western red cedar or western hemlock is most common in juvenile trees, and is not as heavy as on resin producing species such as pine and spruce.

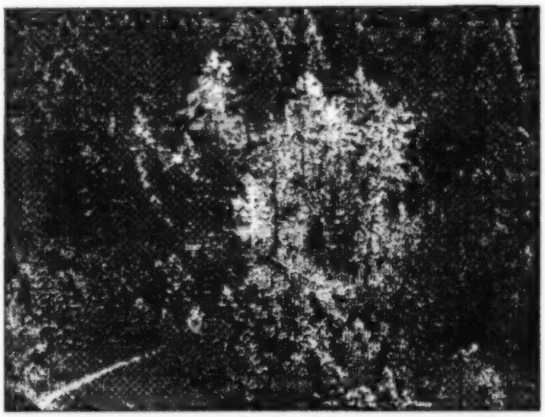
All coniferous species attempt to stop the spread of *Armillaria* infections by producing callused lesions. These lesions appear as flattened canker-like wounds at the base of an infected tree ("cat faces" on cedar). Recently formed lesions are resinous and have mycelial fans beneath the bark. On older lesions, impressions of mycelial fans may be visible on the inner surface of the bark when it sloughs off, or on the face of the scar (3).

As *A. ostoyae* progresses, the fungus begins to decay the wood of a host tree. In its early stages, decaying wood turns a yellowish-brown colour, often appearing water-soaked. As the decay process advances, the infected wood takes on a yellowish, stringy appearance.

DISEASE CONFIRMATION

The following are common signs that confirm the presence of Armillaria root disease in a tree.

Mycelial Fans
Mycelial fans are the most useful diagnostic characteristic of *A. ostoyae* infection in conifers. Early on, creamy white mycelial fans (fungal tissues) appear beneath the bark on the roots of the host tree, and later, on the lower bole. Several years after host death, the fans may disappear from aboveground parts of the tree, but impressions of the fans can remain etched in the inner resin and bark for a number of years (3).



Distinctive *Armillaria* centre in the IDF zone, Invermere Forest District

Rhizomorphs
Rhizomorphs are black root like structures, sometimes described as 'shoe strings'. They initiate new infections and to a limited extent may help the fungus obtain water and nutrients. Rhizomorphs are found on the surface of host roots, and in the soil adjacent to infected stumps and trees. They are usually 1-3 mm. in diameter and are generally dark brown to black but become lighter in colour towards the white growing tips (3). Rhizomorphs of *A. ostoyae* generally spread up to a metre from a host root system (Norris, pers. comm.).

Mushrooms
Armillaria ostoyae reproduces sexually by spores produced by mushrooms (basidiomes). The mushrooms can be used to identify different species of the fungus, and can provide positive identification of *Armillaria* root disease. However, given the similarities between mushrooms of several species of *Armillaria*, identification to the species level requires much experience and expertise. Mushrooms are usually found from August to October at the base of dead or dying trees and stumps.

DISEASE DETECTION AND ASSESSMENT

There are a variety of methods of detecting and quantifying *Armillaria* root disease. The choice of method depends on the nature of the infection (i.e., scattered mortality or infection centers), and forest management goals. Different goals may require estimates of the disease over large areas, or more accurate quantification of the disease over localized areas. The accuracy of any assessment method will be influenced by many factors including the surveyor's ability to recognize the disease. A limitation of all commonly used methods is that they provide an estimate of disease occurrence based on aboveground symptoms only. Research has shown that below ground infections of *Armillaria* root disease are significantly higher than aboveground symptoms indicate.

Ground Surveys
The pixel survey is the most commonly used survey for detecting *Armillaria* root disease in B.C. It is used to determine the proportion of an area that exhibits disease signs and symptoms and is suitable for most stands regardless of whether

Armillaria is expressed in centers, scattered patches, or individual trees.

A pixel survey consists of a series of systematically located transect lines running perpendicular to a baseline. The transect lines are divided into segments, or pixels, which have a fixed length and width. Pixels are identified as being diseased or disease-free, based on the presence or absence of trees signs of *A. ostoyae*. This survey can be done in conjunction with a timber cruise or silviculture survey .

A modification of the pixel survey, the Intensity Measuring Pixel Survey (IMPS), provides an indication of the intensity of root disease on a site. This survey uses a weighting system to account for the fact that small, infected trees may represent less inoculum than large infected trees. IMPS pixels have a fixed length, but the width of each pixel is flexible to ensure that between six and ten trees larger than 12.5 cm. dbh. are included in each sample. Each tree present in a pixel is determined to be healthy or infected, and tallied by four diameter class categories. Infection levels are then calculated using weighted values so that trees in the larger diameter classes are given more weight than those in smaller classes. The survey may provide a more accurate estimate of the actual inoculum load present on a site (Calder, pers. comm. 1994).

The intersection length survey is designed to estimate the percent of an area that is infected with a particular disease. It is useful when infected areas are readily distinguishable from uninfected areas on the ground. A line is surveyed and the surveyor determines where the line enters and leaves infected areas. The proportion of the total length of survey line that falls in infected areas is assumed to represent the percent of area infected. This method is useful when disease centers are small and discrete. Unfortunately, *A. ostoyae* infections are often quite dispersed so this method is of limited use in quantifying the occurrence of *Armillaria*.

Various silvicultural plots may also be used to determine the occurrence of *Armillaria* root disease on a site. Regeneration, tree-growing, and pre-stand tending surveys include a root disease component that requires surveyors to identify and tally infected stems.

Ground surveys can provide a reasonable assessment of disease occurrence (based on above-ground indicators) at the stand level, but are not feasible for landscape level surveys.

A good review of ground survey methods is provided in Nemec, 1992 (5).

Aerial Photography

Aerial photography can be used to estimate disease occurrence over large areas of land, based on stand-level indicators (infection centers and deciduous patches), and individual tree symptoms (red or dead trees). It is also an excellent tool for stratifying areas prior to more intensive ground-based surveys. Limitations of aerial photography include the possible absence of crown symptoms (i.e. in mature cedar and hemlock stands) and the occurrence of other forest pests and pathogens that cause similar symptoms and may be mistaken for *Armillaria* on air photos.

Aerial photography works best on middle-age stands that exhibit crown symptoms, but are not very dense. Recognition of symptoms in species varies considerably. For example, infected subalpine fir and Douglas-fir are easier to identify on photos than infected western red cedar and western hemlock (Reich, pers. comm.). Recognizable symptoms also vary depending on stand characteristics (i.e. age, density, brush); therefore photos are normally backed up by ground surveys.

LIMITATIONS OF SURVEYING *ARMILLARIA* INFECTION

The most significant limitation of the *Armillaria* surveying methods described above is that they measure above-ground symptoms of the disease. These symptoms often don't occur until much of a host tree's root system is infected. Therefore, the actual incidence of infection on a site may be significantly greater than that indicated by above-ground surveys. Research in the Interior Cedar Hemlock zone (ICH) suggests that the below-ground incidence of infection on a site may be up to four or five times greater than above-ground surveys indicate (Morrison, pers. comm.). At present, there is no information to tie the incidence of *Armillaria* seen before harvest to disease development after harvest (van der Kamp pers. comm. 1994).

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FOR MORE INFORMATION CONTACT:

Don Norris, Pathologist
Nelson Forest Region
Tel. (604) 354-6143; e-mail: dnorris

Deb DeLong, Silvicultural Systems Forester
Forest Sciences Section, Nelson Forest Region
Tel. (604) 354-6707; e-mail: ddelong